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MILLING METHODS AT THE QUESTA CONCENTRATOR OF THE MOLYBDENUM CORPORATION OF AMERICA, QUESTA, NEW MEXICO

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MILLING METHODS AT THE QUESTA CONCENTRATOR OF THE MOLYBDENUM CORPORATION OF AMERICA, QUESTA, N. MEX.[1]

By J. B. Carman[2]

INTRODUCTION

This paper, describing the concentrator of the Molygdenum Corporation of America in Taos County, northern New Mexico, 7 miles east of Questa, is one of a series on milling methods being prepared for and published by the United States Bureau of Mines. The mine from which the ore comes is 1¼ miles from the mill, and produces about 40 tons of ore per day by the cut-and-fill method.[3] The ore contains about 5 per cent of MoS_2. The mill has a capacity of 50 tons of ore per day and utilizes flotation methods. Water is taken from Red River. Power is generated by a water wheel, or by a Diesel engine in times of water shortage during the winter. The mill is located close to the bottom of a canyon, in order to obtain maximum head on the water wheel, and the flow of ore is therefore maintained partly by gravity and partly by an elevator and pumps.

ORE TREATED

The MoS_2 content of the concentrator feed ranges from 4.5 to 7.5 per cent. The gangue minerals are quartz, pyrite, altered feldspar, biotite, fluorite, small amounts of rhodochrosite and calcite, and the minerals of the granodiorite country rock.

The molybdenite is not disseminated but occurs as fissure fillings and in brecciated zones of the granodiorite. A portion of it, however, is very intimately associated with quartz or pyrite, and in this form is not readily separated by grinding. The coarse ore has numerous joints or fracture surfaces which are coated with thin black films of molybdenite. Molybdenite of this character can not be split from the rock and this strong mechanical attachment apparently persists even through the grinding process.

The ore in general breaks and grinds readily and the molybdenite is very friable. The run-of-mine ore is 8-inch maximum size and 75 per cent of it will pass through a bar grizzly with 1½-inch spaces. The moisture content of the ore averages 3 per cent.

HISTORY OF OPERATIONS

The first mill was built in 1923, and as originally operated, contained eight 4-foot, Brown pneumatic, matless-type, flotation cells. The froths from the first one to three cells were finished concentrates which contained a maximum of 66 per cent of MoS_2. The froths from the remaining cells were returned to the head cell as middlings.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6551."

[2] One of the consulting engineers, U. S. Bureau of Mines, and manager, Questa property, Molybdenum Corporation of America.

[3] Carman, J. B., Mining Methods of the Molybdenum Corporation of America at Questa, New Mexico: Information Circular, Bureau of Mines, in press.

Three Ruth flotation cells, arranged in parallel, were later installed as cleaners to increase the grade of the finished concentrates. After these cleaner units started to operate, difficulty developed because of the accumulating of slimes in the flotation circuit. The addition of locally made flotation cells for additional cleaning of concentrates further increased the grade of concentrates, but this arrangement seriously increased the amount of middling returns to the head of the flotation circuit and further increased the difficulty due to building up of slimes in the circuit. Three additional Brown flotation cells were then installed for retreating middlings. These cells were later operated as scavenger cells, following the 8-cell rougher machine, and one additional Brown cell was installed to replace them for middlings retreatment.

During 1928 and 1929, preliminary to the construction of a new mill, tests were conducted and experimental changes were made in the flow sheet. A description of this experimental work given in chronological order follows.

Acting on the results of screen assay tests which indicated that concentrator losses occurred in minus 200-mesh sands, the grinding practice was changed to yield finer grinding. The flotation of the finer ground product yielded a higher recovery of molybdenum but a lower grade of concentrates. These tests indicated that net results favored the coarser grinding.

A test was conducted to determine the recovery made by each cell of the Brown 8-cell rougher and the Brown 3-cell scavenger machines. The results of this test indicated that the low solid contents in the pulps treated, caused by diluting water returned to the circuit with middlings, was responsible for low recoveries in the last six cells. An 8 by 14 foot Dorr thickener was added to the circuit to remedy this condition. The treatment of pulps, which contained a higher percentage of solids, reduced the loss of molybdenum in the flotation tailings about 50 per cent. The thickener overflow, however, became muddy after 10 days of operation. This was believed to be due to insufficient thickener capacity, and the test was abandoned.

Three Callow cells were installed to replace the 3-cell Ruth cleaner unit. This change resulted in slightly increased losses of molybdenum in the plus 200-mesh tailings sizes and slightly decreased losses in the minus 200-mesh sizes.

Baffles were added to the Brown rougher machine for the purpose of increasing the percentage of plus 200-mesh MoS_2 floated in the rougher cells. This practice, however, was discontinued.

Sideboards were added to the overflow lips of the Callow cleaners for the purpose of forcing the froth to travel to the heads of the machines for discharge and thus drop some of the gangue. This method of operation improved the grade of concentrates but at the expense of higher losses in the tailings.

Thickening of the middlings pulps before returning them to the head of the flotation circuit was again tested, but this time by the installation of a larger thickener than was at first used for this purpose. The test was not successful, due to the accumulation of colloidal material in the circuit.

The thickened middlings pulp was then returned to the classifier of the grinding unit. The classifier rake speed was decreased and the slope increased for the purpose of preventing the return of fines to the grinding mill. This method of handling middlings returned the slimes to the rougher flotation unit and was abandoned because it produced "wild froth" in the rougher cells which in turn lowered the grade of concentrates without decreasing the loss in the tailings.

The addition of 0.10 pound of caustic soda per ton of ore treated to No. 1 cleaner cell aided the control of froth which had been difficult in the cleaner units due to accumulation of slimes. This reagent increased the grade of cleaner concentrates from 3 to 4 per cent

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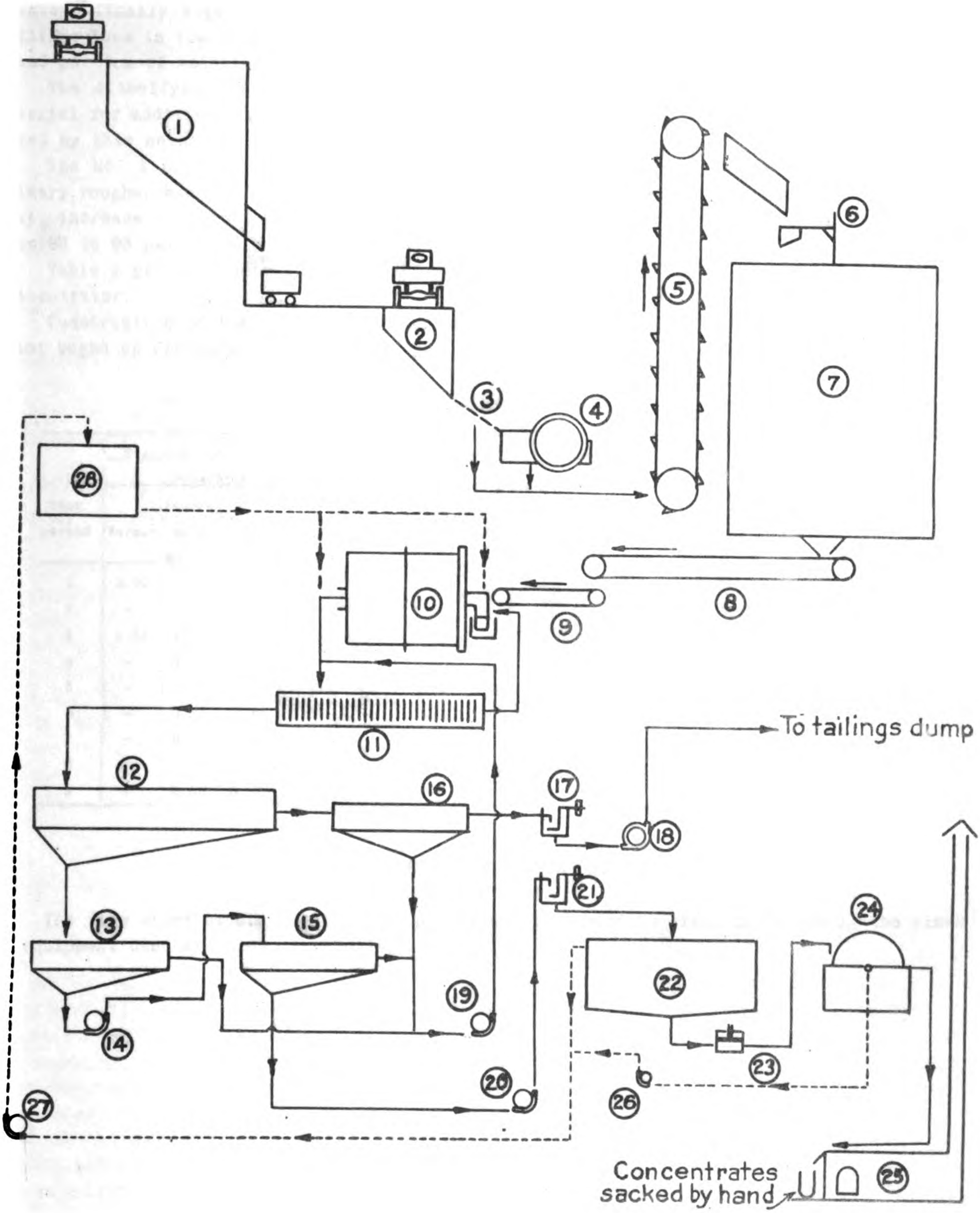

Figure 1.- Flow sheet of ore treatment

and decreased the loss of MoS_2 in the cleaner middlings by 10 per cent. The caustic soda, however, finally began to appear in the mill feed water and this condition increased the tailings loss in the rougher cells. After reducing the amount of caustic soda added to 0.05 pound per ton of material treated, it was finally discontinued.

The classifying of flotation concentrates, with the idea of separating the coarser material for additional grinding, indicated that higher-grade concentrates could not be produced by this method.

The No. 1 cleaner cell was discontinued as a cleaner and was put into service as a primary rougher machine. This change resulted in decreased loss in tailings of 1 to 1.5 per cent, increase of 5 to 6 per cent in the grade of concentrates and an increase in recovery from 88 to 93 per cent.

Table 1 presents metallurgical data during this period of experimental work in the old concentrator.

Construction of the new concentrator was started in 1929 and the operation of this new plant began on February 1, 1930.

Table 1.- Metallurgical data for experimental periods in the old concentrator

Test period	Reagents used per ton of ore treated, pounds							Assays per cent MoS_2			Recovery of MoS_2, per cent	Plus 100-mesh material in heads, per cent	Solids in flotation pulp, per cent
	Pine oils												
	Yarmor	Pensacola No. 100	G.N.S. No. 5	Total	Caustic soda	Sodium cyanide	Xanthate	Heads	Concentrates	Tailings			
1	3.00	3.00	-	6.00	0.09	0.20	-	5.40	73.35	0.58	89.64	4.00	20
2	-	1.60	0.40	2.00	0.09	0.20	-	4.84	72.42	0.46	89.73	1.50	20
3	1.375	1.375	-	2.75	0.09	0.20	-	6.33	71.96	0.68	89.26	3.00	19
4	-	1.65	0.85	2.50	-	0.18	-	6.10	72.50	0.83	86.55	0.70	18
5	-	1.60	0.40	2.00	-	0.16	-	6.19	75.35	0.74	88.30	0.85	18.5
6	-	1.25	0.25	1.50	-	0.14	-	6.30	74.48	0.67	89.36	2.05	20
7	-	0.83	0.17	1.00	-	0.09	-	5.28	75.53	0.78	85.23	2.67	22.5
8	-	0.58	0.12	0.70	-	0.09	0.16	5.70	74.30	0.82	85.64	-	-
9	-	0.83	0.17	1.00	-	0.09	-	5.19	74.50	0.64	87.66	2.00	21

PRESENT METHOD OF CONCENTRATING

The flow sheet of ore treatment as practiced at present is given in Figure 1; the sizes of equipment used are shown in the legend.

Legend for Figure 1

Number[1]	Machines
1	Reserve coarse-ore storage bin, 300-ton capacity.
2	Coarse-ore bin, 12-ton capacity.
3	Bar grizzly, 1¼ inch openings.
4	Universal jaw crusher, 9 by 14 inch.
5	Bucket elevator.
6	Mechanical sampler.
7	Fine-ore storage bin, 100-ton capacity.
8	Belt conveyor, 20-inch.
9	Belt conveyor, 12-inch.
10	Marcy ball mill. No. 54.
11	Dorr simplex classifier, 3 by 18 foot.
12	Callow rougher flotation machine, 2 by 21 foot.
13	Callow primary cleaner, 16-inch by 8-foot.
14	American centrifugal pump, 2-inch.
15	Callow secondary cleaner, 16-inch by 8-foot.
16	Callow scavenger, 16-inch by 8-foot.
17	Mechanical sampler.
18	Wilfley sand pump, 2-inch.
19	American centrifugal pump, 2-inch
20	American centrifugal pump, 2-inch.
21	Mechanical sampler.
22	Dorr thickener, 14 by 8 foot
23	Diaphram pump.
24	American filter, 4-foot, single leaf.
25	Stove for drying concentrates.
26	Cameron centrifugal pump, 1-inch.
27	American centrifugal pump, 2-inch.
28	Storage tank for mill water.

[1] Numbers correspond to numbers given in Figure 1.

Coarse Crushing

Ore is transported from the mine to the concentrator in automobile trucks during the day shift only. At the concentrator, the trucks dump the ore into a 12-ton capacity bin which serves the crusher. If this small bin is full, the ore is delivered to a 300-ton capacity storage bin from which it is transported to the crusher bin in a 1-ton capacity mine car.

The Universal 9 by 14 inch jaw crusher is driven by belt and is set at 1½-inch openings. A bar grizzly, with 1½-inch openings, is placed between the bin and crusher. The crusher has capacity to handle 60 tons of Questa ore per eight hours but crushes, on the average, about 16 tons per eight hours. The crusher product contains about 5 per cent plus 1½-inch ring size and about 40 per cent minus ½-inch ring size. It joins the undersize of the grizzly and is delivered to a 100-ton capacity fine-ore bin by a bucket elevator.

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Grinding

From the fine-ore bin the ore is delivered to a 20-inch conveyor belt, feeding a 12-inch conveyor belt which in turn feeds a No. 54 Marcy ball mill. The ball mill which operates in closed circuit with a Dorr rake classifier is driven at a speed of 27 r.p.m. through a friction clutch and is equipped with a grate discharge which has 3/16-inch openings.

The ball load is maintained at about 4,200 pounds by the addition of 4-inch forged steel balls. Ball consumption amounts to about 1½ pounds per ton of ore ground.

Liners are of molybdenum-chrome steel, and liner consumption amounts to 0.934 pound per ton of ore ground.

During the first ten months of operation in 1930 the Marcy mill operated 6,878 hours out of a possible 6,936 hours. During this period, one set of side liners was replaced and various construction difficulties were encountered, but the lost time amounted to less than 1 per cent.

The 3 by 18 foot Dorr classifier which operates in closed circuit with the Marcy mill is set at a slope of 2¼ inches to the foot, and the rakes have a speed of 12 strokes per minute.

The launder used to convey the ball-mill discharge to the classifier has a slope of 1½ inches per foot and is lined with 3/16-inch steel plate. The launder which returns classifier sands to the ball mill has a slope of 3¼ inches per foot; this slope is the maximum that could be obtained with the set-up that existed at the time of rebuilding the mill.

Pulp density in the ball mill is maintained at about 80 per cent of solids and that in the classifier from 20 to 22 per cent of solids. The classifier is equipped with a hydrometer, installed at the overflow end, to assist in maintaining the desired pulp density. The hydrometer operates a pointer which indicates the percentage of solids in the classifier on a dial. The dial is visible from various distant points of the building. This arrangement has proved to be of great value in indicating quickly such conditions as changes in water or ore feed or a change in the character of the ore.

The Marcy mill is at present grinding about 39 tons of ore per 24 hours and the classifier is handling a circulating load of about 280 per cent based on new ore feed. Both machines are operating far below their capacities.

Table 2 presents typical screen analyses of final and intermediate grinding products and also indicates the percentage of solids in the various pulps.

Table 2.- Typical screen analyses of final and intermediate grinding products

	Test 1			Test 2			Test 3		
	Ball mill discharge, per cent	Classifier sand, per cent	Classifier overflow, per cent	Ball mill discharge, per cent	Classifier sand, per cent	Classifier overflow, per cent	Ball mill discharge, per cent	Classifier sand, per cent	Classifier overflow, per cent
Solids in pulp	80.0	70.00	20.5	85.0	68.0	21.0	77.9	70.0	20.0
Screen sizes, mesh:									
Plus 10	1.33	1.72	-	1.49	1.92	-	1.91	1.85	-
Minus 10 plus 20	3.60	3.69	-	3.48	6.75	-	6.18	3.26	-
Minus 20 plus 30	7.11	7.61	-	6.60	7.75	-	6.98	5.74	-
Minus 30 plus 40	8.76	8.75	-	7.60	10.05	-	7.38	8.56	-
Minus 40 plus 100	44.89	48.05	0.85	40.00	45.40	0.51	35.92	45.05	0.68
Minus 100 plus 150	12.76	14.00	9.48	14.55	14.01	7.88	14.45	17.05	9.87
Minus 150 plus 200	11.30	10.01	20.80	13.00	8.11	17.39	12.90	11.65	16.44
Minus 200	10.01	6.56	68.38	12.65	5.16	73.49	13.28	6.60	72.01
Total	99.76	100.39	99.51	99.37	99.15	99.26	99.00	99.76	99.00

Flotation

The classifier overflow pulp is treated in a Callow rougher machine. The rougher produces concentrates which are cleaned in two stages of callow cells. The tailings of the rougher are treated in a Callow scavenger cell which produces final waste tailings. The middlings products from the primary and secondary cleaner cells together with the froth product of the scavenger cell are returned to the head of the flotation circuit.

The Callow rougher is a 7-pan 2 by 21 foot machine. The cleaner and scavenger units are 4-pan 16-inch by 8-foot cells. These cells are equipped with 4-ply, ¼-inch square stitched canvas blankets. The blankets of the rougher and scavenger cells have a life of about six months and those of the cleaner cells last somewhat longer.

Air is supplied to all flotation cells at a pressure of 4 to 4½ pounds per square inch by a No. 2 belt-driven Root blower. The volume of air consumed amounts to about 800 to 900 cubic feet per minute which is equivalent to about 8 cubic feet of free air per square foot of blanket area per minute. The blower is at present located in the mill building, but it is planned to move the blower to a position outside the building because dust in the air accumulates on the rotors and increases friction losses. Forced oil feed is required to lubricate the bearings, which tend to become gummy.

The flotation reagents used comprise Pensacola No. 100 pine oil, used as a collector; G. N. S. No. 5 pine oil, used as a frother; and sodium cyanide, used to depress pyrite. The pine oils are mixed in the proportion of 5 parts of Pensacola to 1 part of the G. N. S., by volume, and the mixture is added to the ball mill scoop box at the rate of 1 pound per ton of ore. The sodium cyanide is added to the secondary cleaner as a 10 per cent solution at the rate of 0.08 pound per ton of ore by a disk and cup type feeder.

A sketch of the feeder used for the pine-oil mixture is presented in Figure 2. A board is caused to slide vertically up and down in wooden guides by means of a crank arm fastened to a speed reducer and driven by a belt from the same counter shaft which drives the ball-mill feed conveyor. A small cylindrical cup is attached to the lower end of the board by means of metal strips which form a fork. The lower end of the cup is fastened to a wire pivot which is held by the forked strips. A length of heavy wire is welded to the wire pivot and slides over a guide pin which is attached to the framework of the device by a metal strip. As the cup goes down, the wire which slides over the guide pin causes it to assume an erect position, and it is filled with the liquid into which it dips. As it rises on the upstroke above the edge of the pan holding the reagent, the wire slides forward over the guide pin and causes the cup to tip forward. According to the position of the guide pin and the shape of the slide wire, the cup tips more or less, and a part of its content is emptied onto the lip on the edge of the pan and flows by gravity through a small pipe to the ball-mill scoop box.

The principal reasons for the use of pneumatic flotation machines at this plant are low power requirements, simplicity of installation and upkeep, and ease of operation as compared to machines of the mechanical agitation type. It was, moreover, known that they would give satisfactory differentiation between the molybdenite and the pyrite, for the pyrite in the ore appears to be slightly tarnished as it comes from the mine and is therefore readily depressed.

Sideboards are used on the two cleaner machines to force the froth to travel from the lower end to nearly the head end before being discharged. This method of operating gives cleaner concentrates, because of the increased opportunity to drop gangue and middlings particles.

Metallurgical data of the flotation circuit is given in Table 3.

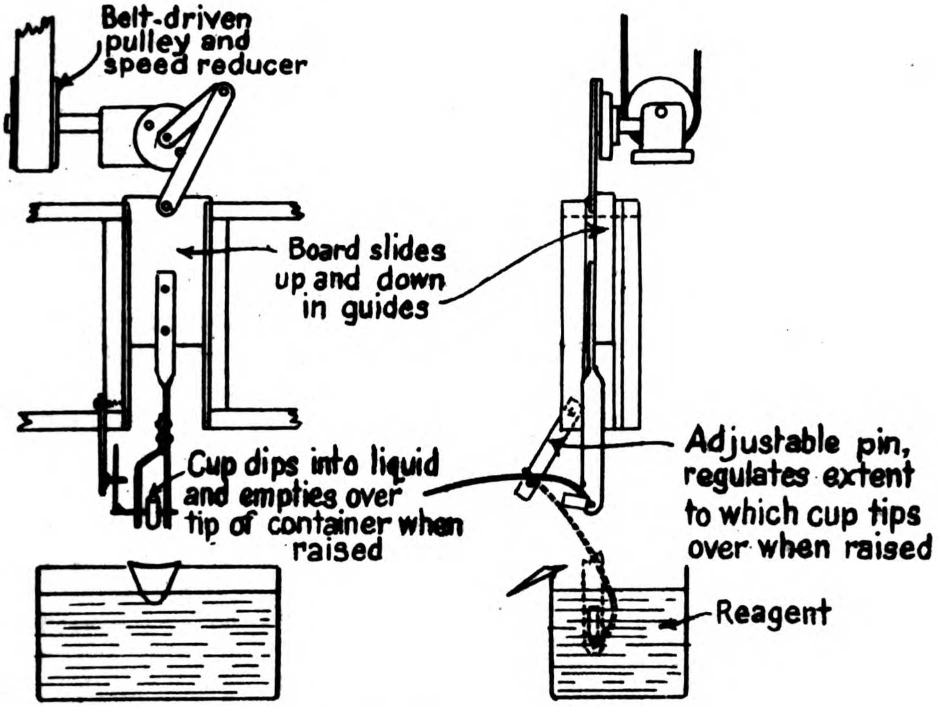
Belt-driven pulley and speed reducer
Board slides up and down in guides
Cup dips into liquid and empties over tip of container when raised
Adjustable pin, regulates extent to which cup tips over when raised
Reagent

Figure 2.- Flotation-reagent feeder

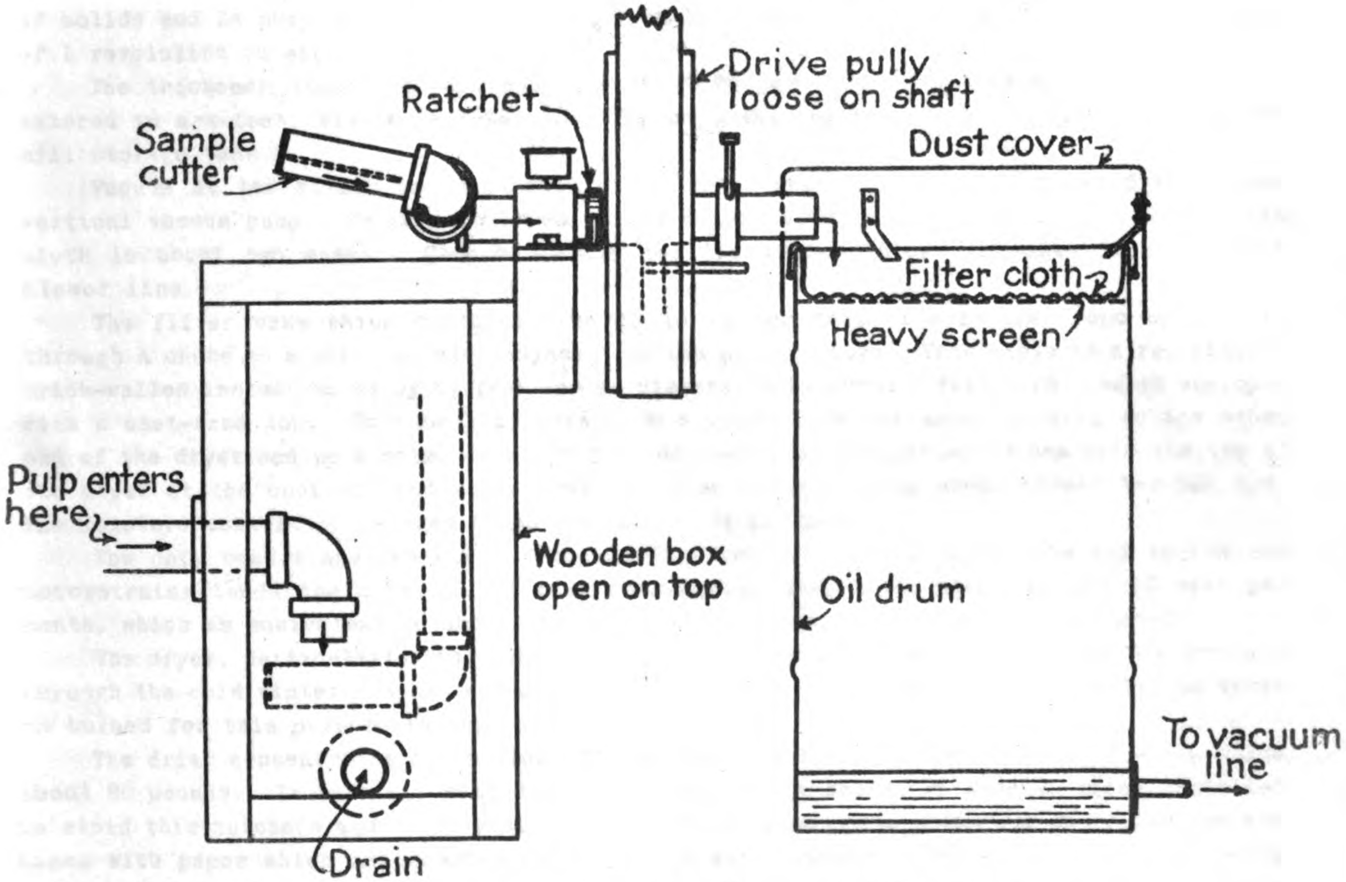

Figure 3.- Automatic sampler

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Table 3.- Flotation circuit metallurgical data

	MoS_2, per cent
Rougher cell:	
Heads, not including middlings returned	5.2
Concentrates	30.0
Tailings	0.9
Primary cleaner cell:	
Concentrates	55.0
Middlings	4.0
Secondary cleaner cell:	
Concentrates	74.5
Middlings	7.0
Scavenger cell:	
Concentrates	1 to 3
Tailings	0.6
Recovery in final concentrates	87.7

DEWATERING AND HANDLING OF CONCENTRATES

The finished concentrates pulp of the secondary cleaner cell contains about 8 per cent of solids and is pumped to a 14 by 8 foot Dorr thickener, which operates with a rake speed of 1 revolution in eight minutes.

The thickener underflow pulp contains about 25 per cent of solids and is further dewatered in a 4-foot, single-leaf American filter. The thickener overflow is pumped to the mill storage tank.

Vacuum at the filter is maintained at about 17 inches of mercury by an 8 by 5 inch vertical vacuum pump. Palma reinforced canvas-twill filter cloth is used; the life of the cloth is about two weeks. Compressed air for the filter "blow" is taken from the Root blower line.

The filter cake which contains from 10 to 12 per cent of moisture drops by gravity through a chute to a shelf located adjacent to the drying stove. This stove is a rectangular brick-walled inclosure, 4½ by 6½ feet inside dimensions by about 3 feet high, and is equipped with a cast-iron top. Soft coal is burned on a grate, the hot gases passing to the other end of the dryer and up a metal chimney. The concentrates are pulled by hoe onto the top of the dryer at the cool end and worked over as they are gradually moved toward the hot end. The moisture content is reduced to an average of 3½ per cent.

The only cost connected with drying is for fuel, as the man who sacks and weighs the concentrates tends the dryer. The fuel consumption amounts to about 6 tons of coal per month, which is equivalent to about 1½ pounds of coal per pound of water eliminated.

The dryer, particularly the smoke pipe, performs the additional duty of heating the mill through the cold winter months, and some part of the coal used for drying concentrates would be burned for this purpose in any case.

The drier concentrates are pulled off the dryer by hoe into sacks, each of which holds about 80 pounds. In sacking, some dust is stirred up; a collector hood is being installed to avoid this nuisance and to prevent loss of concentrates. The sacks are of burlap and are lined with paper which is cemented to the cloth with asphalt. These sacks cost 14 cents each, and although they constitute one of the largest supply costs for the mill they are very satisfactory. Heavy jute sacks with canvas liners were tried, but they weighed more and the

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loss in and through the fabric was considerable, in spite of a thorough dusting out at the receiving end. The sacks are not reused because of their loss of strength. They are burned to recover the concentrates which can not be removed by shaking.

The sacks are closed by being sewed with twine, after which they are weighed on platform scales, tagged, and stored for shipment.

DISPOSAL OF TAILINGS

The tailings pulp from the scavenger flotation cell is pumped to the tailings pond by a 2-inch Wilfley sand pump. The pipe line discharges into a wooden launder, 4 by 4 inches inside dimensions, located at the tailings dam. This launder is set at a slope of ⅛ inch per foot around the edge of the dam. Holes are bored at regular intervals in the bottom of this launder to permit the tailings to drop into a short distributing launder. The later has notched edges to spread the material evenly as possible and thus prevent its piling up; it is moved from point to point along the dam as desired. A low wall is heaped up, by shoveling, a few feet outside the line of the main launder to retain the tailings. The clear water flows through a stand pipe located in the middle of the pond and is discharged into the river.

WEIGHTING, SAMPLING, AND ASSAYING

The concentrator heads are sampled as the ore stream is discharged into the fine-ore bin. A mechanical sampler, which consists of a box slowly rotated on the end of an arm 3 feet long, cuts the ore stream and removes 4 per cent of the heads as a sample. The box, after cutting the ore stream, is discharged by a tripper which opens the counterweighted bottom. The 24-hour sample is reduced to about 500 pounds by shoveling. This heads sample has been found to give inaccurate and erratic results. The error apparently increases with the moisture content of the ore and is found to be a minimum when the moisture content of the heads is around 2½ per cent. The heads sample is used for determinations of molybdenum and moisture contents of the concentrator feed.

The tailings sample is obtained by a mechanical sampler located between the scavenger flotation cell and the Wilfley sand pump. Referring to Figure 3, a pulley which is driven by belt is mounted loosely between collars on a length of pipe. One end of the pipe passes through a bearing which in turn is mounted on the side of the sample box, and continues through a 90° elbow, another length of pipe, and a second elbow, to the cutter itself. The latter consists of a length of 2-inch pipe about 6 inches long, closed at the far end and having a narrow slot cut in the side which is uppermost when the sample pipe is in the position shown by the dotted lines. The sample consists of the amount of pulp which enters the slot as the pipe passes through the stream. As the pulley turns slowly, a stud which is set in one of its spokes strikes a long set-screw attached to a collar on the shaft pipe, causing it to turn. When the sample pipe just passes its highest point of travel, gravity causes it to fall swiftly, the sample being cut at the lowest point of travel as the cutter passes through the stream of pulp. The momentum of the falling cutter causes it to pass more than halfway up the other half of a complete revolution. A ratchet and spring arrangement on the shaft-pipe prevents it from falling backward, and holds it in such a position that the sample drains out through the radial arm and the shaft into a filter. The latter is made from an oil drum, by removing the head, tapping a pipe into the bottom for connection to the mill vacuum line, and attaching a screen near the top of the drum. A muslin filter cloth fastened to a snug-fitting wire hoop is put over the top of the drum and rests on the screen. a loose-fitting cover is provided, slotted at one side to pass over the pipe shaft of the sampler. The filtrate water, which is perfectly clear, is discharged intermittently from the drum, as required, by opening a valve in the suction line. Filter paper was formerly used in place of muslin but was found to be more expensive, as it could be used only once, whereas the muslin is washed and reused.

The 8-hour sample which amounts to about 1/900 cut weighs about 30 pounds. It is discharged from the filter into a tub and dried on a stove. The tailings sampler has been found to produce accurate samples.

A similar sampler is used to take shift samples of the concentrates from the secondary flotation cleaner cell. The 8-hour concentrates sample weighs about 30 pounds and is used only for operating control

All ore is weighed in the trucks before being dumped into the mill bins. The weight of fine ore sent to the ball mill is determined by collecting the discharge from the conveyor belt at ½-hour intervals, for a known length of time. All such samples are weighed. and the weights are averaged for each shift. The weight as determined by this method usually agrees with the truck weighings within 1 ton per month.

All concentrator samples are assayed by a volumetric method, which follows, in the main, the procedure described by J. P. Bonardi in United States Bureau of Mines Bulletin 212, Analytical Methods for Certain Metals, page 109. A weighed portion of the sample is fused with sodium peroxide, dissolved in water, and the solution filtered. A Jones reductor is used to reduce the molybdenum, after which titration is performed with a potassium permanganate soution which has been standardized against sodium oxalate obtained from the Bureau of Standards. All results are expressed in percentage by weight of MoS_2. About half the time of one man is devoted to assaying the mine and mill samples.

WATER SUPPLY

An ample supply of water for milling and camp use is available in Red River. The minimum creek flow is about 10 second-feet, which is more than ample for mill requirements.

The fresh water supply may be taken from the pipe line which serves the Pelton wheel or directly from the river bottom above the mill through a pipe line which discharges by gravity into a sump in the mill. Water for camp use is elevated to the camp water-supply tank from this sump by a Goulds triplex pump.

The water is relatively soft and does not contain impurities harmful to milling operations except during intervals in spring and early summer when the river water is muddy enough to interfere with flotation operations. At such times water for milling purposes is obtained from a small stream leading into Red River directly across from th mill. This water flows by gravity through a pipe line which crosses the river and connects with the mill supply system.

The new water consumption amounts to about 2½ tons per ton of ore milled. An approximately equal amount is returned to the ball-mill circuit in the middlings pulp and some is reclaimed by the thickener and filter.

The thickener overflow water and the water from the filter are collected in a small sump and lifted by a 2-inch American centrifugal pump to the mill water-supply tank located at the head of the mill.

The camp uses about 6 gallons of water per minute from the camp supply tank. Probably not over 150 to 175 persons out of a total of 250 use this supply.

POWER

Power for milling operations is furnished by a water wheel, except in winter months when the water is low. During the low-water period a Diesel engine provides the power.

The water wheel was installed when the mill was built in 1923, and at that time sufficient water was available for continuous operations on the basis of 20 tons daily capacity. When the mill was rebuilt in 1930, however, it was known that sufficient water power would not be available during the entire year, and the engine was installed at that time.

Water for the operation of the wheel is diverted from Red River by a small, cribbed, rock-filled dam, which is about 20 feet wide and 4 feet high; it flows through a wooden flume, a distance of 6,800 feet to the penstock above the wheel.

The water drops from the penstock to the wheel through two 16-inch diameter straight-riveted, flanged pipes, which join in a short length of 20-inch diameter pipe at the bottom. The second pipe was added when the mill was rebuilt. The intake pipes are 400 feet long and the head on the wheel is 110 feet.

The power element is a Pelton water wheel which has a pitch diameter of 66¼ inches and which is equipped with a 5 7/16-inch shaft. This wheel was originally designed to deliver about 350 hp., and was obtained secondhand for this installation. Its speed under the present normal load is 146 r.p.m. The original 4¼-inch nozzle was replaced by a double nozzle having one 3-inch and one 4-inch opening.

The wheel is connected by belt to the main drive shaft of the mill through a jaw clutch. A 15-kilowatt, 110-volt, direct-current generator, connected to the wheel by belt, supplies power for electric lighting. A 24-inch Pelton wheel drives this generator when the larger wheel is not in operation. A third and still smaller wheel furnishes power for the machine shop.

The construction of the flume which is used at present for conveying water to the Pelton wheels is shown in Figure 4. This flume normally carried about 15 inches of water at a velocity of 4 feet per second, a flow which amounts to approximately 14 second-feet. It is set on a grade of 1½ feet per thousand feet and was built at a cost of $2.50 per foot. It is equipped with a sand box located about 200 feet from the upper end which effectively prevents the accumulation of sediment in the flume.

The engine is a 4-cycle, 4 cylinder, Chicago-Pneumatic, 10¾ by 13¾ full Diesel type. It is rated at 160 hp. at sea level and delivers 119 hp. at its present altitude of 8,100 feet. The engine is equipped with a Midwest intake air filter, a De Laval oil separator which removes considerable carbon from the lubricating oil, and an exhaust muffler pot which very successfully eliminates the noise of the exhaust. Cooling water on leaving the engine goes to a riffle-type cooler on the roof of the building and from there to a 3,000-gallon capacity water tank. Starting air at 350 pounds pressure is furnished by a 2-stage vertical 4½ by 2 by 4½ inch Gardner-Denver "Rix" compressor, which is connected by belt to a 5 to 8 hp., 1-cylinder, New-way air-cooled gasoline engine. The Diesel engine is connected by belt to the main shaft through a friction clutch. A jaw clutch in the main shaft disconnects the Diesel pulley when the engine is idle.

Comparative operating costs for power generated by the Pelton water wheel and by the Diesel engine are presented in the tabulation which follows.

Operating costs for power generated by the Pelton
water wheel and the Diesel engine

Pelton water wheel	Cost per hp. hour	Diesel engine	Cost per hp.-hour
Operating labor....	$0.000833	Fuel oil	$0.00738
		Lubricating oil	0.00041
			$0.00779

These operating costs are based on the following data: Operating labor for the water wheel consists of part of the time of one man to inspect and repair the flume. Operating labor is not charged to the engine, as an increase in force does not result from its use. The cost of operating and repair supplies for the wheel is negligible. The engine consumes 125 gallons, or 815 pounds of fuel oil per 24 hours at an average three-quarters load, at 1.845 cents per pound. It also uses 0.0546 gallon of lubricating oil per hour at 75 cents per gallon. The average output of both prime movers is estimated at 100 hp.

The cost of installing the Pelton wheel and flume line was about $23,000. That of the Diesel engine and all accessories, including the building and foundations, was about $15,000. Repair costs on the Diesel during its first year of operation have been negligible, and offer no basis on which to estimate this item for the future. Repair costs on the flume will doubtless increase. The saving in power cost by the use of available water power amounts to over $500 per month. The operating cost for Diesel power at this plant is ten times that of water power.

CONVEYING AND PUMPING

A bucket elevator receives the broken ore and by-passed fines below the jaw crusher and elevates these products about 22 feet to the top of the fine-ore bin.

A 24-inch conveyor belt, 15 feet long, delivers the ore from the fine-ore bin to a 12-inch cross conveyor belt, which in turn feeds the ball mill. The 24-inch conveyor is driven intermittently by a ratchet and pawl feeder, and the speed of this belt, which averages about 20 inches per minute, governs the rate of feed to the ball mill.

The classifier overflow pulp is conveyed by launder to the rougher flotation machine. The concentrates froth from the rougher flows by launder to the primary cleaner. The concentrates froth from the primary cleaner cell is pumped to the secondary cleaner and the froth from that machine is pumped to the thickener by 2-inch American centrifugal pumps. The rougher-cell tailings are conveyed by launder to the scavenger machine. The middlings of the cleaner cells and the froth from the scavenger machine are collected in a sump and returned to the ball-mill discharge by a 2-inch American centrifugal pump. Tailings from the scavenger cell are elevated about 25 feet by a 2-inch Wilfley sand pump and discharged into a 2-inch pipe line which extends on a down grade to the tailings pond.

The pumps mentioned are each driven by belt. The launders, 8 inches wide and 6 inches deep inside, are made of 1-inch lumber and placed on a slope of about ¼ inch per foot, with the exception of the froth launder from the rougher to the primary cleaner, which has a slope of about ¾ inch per foot. The launders are not lined.

CONCENTRATOR LOSSES

From the results of microscopic analyses, made prior to 1930, using magnifications of 30 diameters, it was concluded that grinding to minus 150-mesh size liberated practically all of the MoS_2 from the gangue. At this time, therefore, it was believed that all losses of MoS_2 in tailings were due to the presence of slimes contained in the flotation pulp.

The ore contains some primary slimes but probably not in sufficient quantity to interfere with flotation results, and it was therefore concluded that the losses were occasioned by slimes produced in grinding operations.

The installation of a grate-discharge ball mill decreased the amount of slimes produced in grinding operations, but large amounts are still produced and efforts have been made to further decrease the slime content of the flotation pulp.

At times the concentrator feed has contained large amounts of kaolin or other talcose alteration products, but the removal and separate treatment of such material has never been considered because of the small amounts present and the assumption of increased operating costs for such procedure.

Early in 1930 a microscope capable of magnifying 250 diameters was acquired, and its use revealed that the MoS_2 was not liberated as completely as was formerly believed. Microscopic analyses indicated that from 70 to 80 per cent of the MoS_2 contained in the tailings was attached material.

Particles of quartz and pyrite which had appeared perfectly barren at magnifications of 30 diameters were seen to have numerous extremely small particles of molybdenite attached to them. The microscope likewise showed that 60 to 70 per cent of the gangue contained in the concentrates was attached to molybdenum sulphide. It was evident that crushing sufficiently fine to liberate such material was impracticable, and at the same time it was concluded that slimes contained in the flotation circuit had not been as serious a cause of loss as was formerly believed.

Experimental work is being carried on with the object of recovering more of the attached MoS_2, which is at present lost in the tailings. If the flotation of these included grains proves feasible the grade of concentrates can be improved by additional grinding and flotation of the middlings product obtained in a separate unit.

LABOR

The mill crew consists of one man at the crusher during day-shift only; one operator on each shift who tends to the ball mill, flotation machines, and other mill machinery; one filter man for each shift who also takes care of drying and sacking the concentrates; half of the time of a repairman on day shift, one assayer on day shift, and a superintendent, or a total of 9½ man-shifts per 24 hours. The assayer's time is only partly spent on mill work, the rest being devoted to assaying mine-ore samples and to duties in the store and warehouse.

MISCELLANEOUS

The mill is of frame construction, with concrete foundations and floors. It is heated by the dryer stove and two coal-burning heaters, one of which is also used to dry samples. Fire protection consists of soda-acid fire extinguishers and a fire hose connected to the high-pressure water line.

METALLURGICAL DATA AND COSTS

Table 4; a summary of concentrator costs for the same period is given in Table 5; and
Metallurgical data for the period February 1 to November 30, 1930, are presented in
Table 6 shows costs in units of labor, power, and supplies.

Table 4.- Metallurgical data, February 1 to November 30, 1930

Ore treated, wet tons	11,239
Days operated	289
Hours operated per day	23.80
Average ore treated per day, tons	38.9
Concentrates produced, tons	673
Average concentrates produced per day, tons	2.33
Ratio of concentration, tons into 1	16.7
Feed, per cent of MoS_2	5.03
Concentrates, per cent of MoS_2	71.13
Tailings, per cent of MoS_2	0.68
Recovery of MoS_2, per cent	86.8
New water consumption per ton of ore treated, tons	2.5
Ball consumption per ton of ore, pounds	1.5
Liner consumption per ton of ore, pounds	0.934
Cyanide used per ton of ore treated, pounds	0.08
Flotation oil per ton of ore treated, pounds	1.00

Table 5.-Summary of concentrator costs, February 1 to November 30, 1930

	Cost per ton of ore treated
Breaking:	
Labor	$0.14
Concentrating:	
Labor, operating, including supervision	1.07
Supplies, operating	.90
Assaying:	
Labor	.12
Supplies	.06
Repairs:	
Labor	.20
Supplies	.05
Power	.15
Total	$2.69

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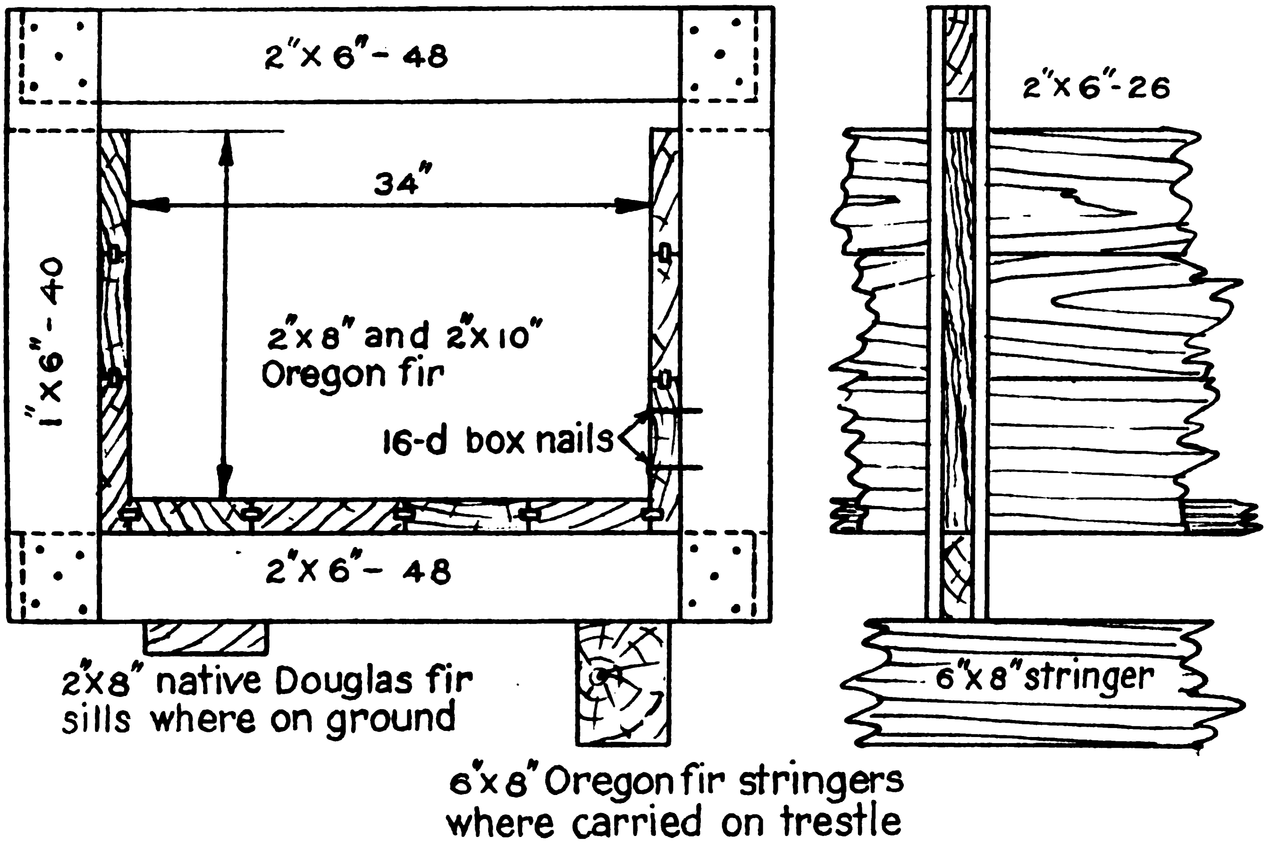
Table 6.- Concentrator costs in units of labor, power, and supplies

	Tons per 8-hour man-shif	Man-shifts per ton
Labor:		
Breaking	39	0.0256
Milling, which includes grinding, classifying, and flotation	13	.0770
Dewatering and handling concentrates, including filtering, drying, and sacking	13	.0770
Tailings disposal	156	.0064
Assaying	39	.0256
Supervision	39	.0256
Miscellaneous	156	.0064
Average or total	4.11	0.2436

	Kilowatt-hours per ton
Power:	
Breaking and elevating	1.1
Grinding	20.0
Classifying	2.6
Flotation	13.3
Dewatering and handling concentrates	5.5
Tailings disposal	2.6
Water supply	1.3
Total	46.4

Supply Consumption and Cost of Supplies:	
Reagents, pounds per ton:	
Cyanide	0.08 at $0.24 per pound = $0.02 per ton of ore
Flotation oil	1.00 at $0.73 per gallon = $0.09 per ton of ore
Miscellaneous:	
Balls, pounds per ton	1.5 at $0.053 per pound = $0.08 per ton of ore
Ball mill liners, pounds per ton	0.934 at $0.150 per pound = $0.14 per ton of ore
Sacks, number per ton	1½ at $0.14 = $0.21 per ton of ore
Coal for heating and drying, pounds per ton	22.4 at $14.60 per ton = $0.18 per ton of ore
Other supplies	$0.18 per ton of ore
Total operating supplies	$0.90 per ton of ore



Note: Box is made of select common Oregon fir, surfaced on two sides, edges plowed 1/2 by 1/2 inch, in 16-foot lengths. Collars are of native pine and are spaced at 4-foot centers, every fourth collar having 4 by 6 inch top and bottom, and 4 by 6 inch fillers at the sides, to give nailing space at the box joints. Splines are of 7/16 by 15/16 inch white pine. The box is boarded over and heaped with earth, where possible, to prevent freezing. The grade is 1 1/2 feet per 1,000; average depth of water is 15 inches; velocity, 4 feet per second

Figure 4.- Flume for water-power plant